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(2018)

Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 23 (2018) 267–272

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation

Industrie 4.0 – Competencies for a modern production system

A curriculum for Learning Factories

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Abstract

Industrie 4.0 promises new digital solutions to optimize the entire value stream in manufacturing systems. Existing production systems are often based on the continuous improvement philosophy of lean management. New opportunities for developments arise from the combination of Industrie 4.0 and Lean. While the qualification of employees for such complex production environments plays a key role, the learning factory concept offers a promising approach to competency development in this field. In this paper, required competencies to enable a successful integration of lean management and Industrie 4.0 are discussed and analyzed. Furthermore, they are structured and presented in a comprehensive Lean 4.0 curriculum.

Peer-review under responsibility of the scientific committee of the 8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation.

Keywords: industry 4.0, lean management, competency, learning factory

1. Introduction

As the requirements and challenges for today's industrial companies change, so are their corresponding learning environments driven to adapt. New findings and insights from research and industry request a change or modification

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2351-9789
Peer-review under responsibility of the scientific committee of the 8th Conference on Learning Factories 2018 - Advanced Engineering Education & Training for Manufacturing Innovation.
10.1016/j.promfg.2018.04.028

on the focus and content for existing educational offers within these institutions. This is especially true in the light of the fourth industrial revolution (Industrie 4.0) which demands new competencies for blue as well as white-collar workers. Learning factories can be seen as models of real factories that are used for education and training and must therefore adapt to these new challenges [1]. The integration of new competencies in existing curricula is crucial for the sustainable business of a learning factory.

Methods and tools were developed to support a competency-oriented design of learning factories on different design levels. Thereby, it gets easier and faster to conduct even big changes regarding the targeted competencies as well as the organizational, technical or didactical structure of the learning factory. The article gives an overview about new findings related to Lean 4.0. Furthermore, it presents the competency-oriented design of learning factories in general and the design of a new Lean 4.0 curriculum in particular. Finally, the content of a new learning module is described in more detail.

2. Lean 4.0: Integrating Lean and Industrie 4.0

Lean Production is a value-based approach where employees are constantly improving processes by eliminating waste and systematically solving problems, and in doing so become better problem solvers themselves. In the center of the lean production stands the concept of a continuously operated plan, do, check and act process (PDCA). Also, the digitalization of the industrial production gives companies the ability to improve their products and processes [2] – a field in which the philosophy of Lean Production is effectively established in industry. Even though a great number of companies made statements about implementing new IT systems to connect machinery, workers and products [3], the question has been raised what the future position of the production workforce may be. For sure their daily tasks and necessary competencies may change but they still will be essential to maintain machinery or solve problems in a future connected production environment [4]. The German coined term Industrie 4.0 holds the connected factory as a core value – every product connects itself with its counterparts and machineries. The concept bears great potential to relieve workers from monotonous tasks and improve the quality of decisions on the shopfloor [4].

Both approaches, Lean Production and Industrie 4.0, are similar in terms of their goals:

- Lean Production pursues the goals of time, quality, costs, safety and workers motivation [5]
- Industrie 4.0 adds the elements of individualization, new business models and connected systems (which human workers do not necessarily need to comprehend as long as the possibility of maintenance is given) [6]

	Lean Production		Industrie 4.0
Approach	holistic (human + technology + organisation)	⇔	technology driven
Philosophy	people development + problem solving	⇔	feasibility, (self) optimisation
Foundation	stability and standardisation	+	interconnectivity, adaptivity
Control principle	flow, pull, FiFo	+	dynamic, depending on current situation
Improvement + problem solving	proactive → standard, abnormality → reactive	+	data based learning → predictive
Information acquisition	real place, real material (‚Go and See')	+	problem specific data provision, ‚real time'

Fig. 1. Different approaches for similar targets [7].

The question is, where both approaches align and where they follow different paradigms: Lean production stresses stability and standardized products, whereas Industrie 4.0 propagates self-controlling processes and correlation before causality [6]. The Andon principle – a sequence to find and solve problems where a production line can be stopped

by anybody, who finds an error – is abandoned towards an unlinked production line, in which every work step takes place individually. Therefore problems in one workstation do not influence the others; however, the need to solve problems directly after their first occurrence evaporates [8]. Fig. 1 shows some of the differences Industrie 4.0 and lean production do hold.

Therefore, Metternich et al. (2017) propose, that digitalization of Lean Production with the aim to improve the Lean approach instead of replacing it, bears the future of improving production environments [7]. Digitization comes too early, where processes are unstable, standards do not exist and basic key performance indicators are missing. Only when a team understands the mindset of Lean Production and applies its tools confidently, digitization will provide the next productivity boost. In addition, digitization cannot replace the value-oriented approach of Lean Production, e.g. the development of employees' competencies through targets states, on-site leadership and the philosophy of continuous improvement through systematic problem-solving. The combination of the two concepts can be coined under the term "Lean 4.0". Four areas of action can be identified where Lean Production benefits from Industrie 4.0.

1. *Digitization improves the production with the customer demand undergoing disruptive changes through digital business models:* In production, decreasing time and costs and improving quality remain the dominant key targets. Flexibility and individuality are becoming increasingly important. On the market side, there is a risk that new, digital approaches will threaten and possibly even replace existing business. Where new services can be offered to the customer through the digitization of internal processes and a corresponding payment model generates new sales, a new business model can be created. This does not necessarily need to arise from cyber-physical systems.
2. *Real-time data creates new opportunities for existing methods of Lean Production:* Lean Production and Industrie 4.0 are in clear opposition, where the improvement cycle, consisting of standardization, deviation detection, problem solving by employees and subsequent improvement, is interrupted by Industrie 4.0. An opportunity of Industrie 4.0 lies in the exchange of real-time data between any process steps. This can eliminate one of the major weaknesses of previous digital planning and support systems, the lacking up-to-date information. Inflexible standards can be overcome by situation-specific information provision on-site in real time, without giving up pull, takt or first-in-first-out-sequence.
3. *Digitization helps to establish Lean Production in new areas like make-to-order business:* In small batch production, make-to-order business or production with large work scopes, standardization was not accomplishable in the past. In the future, work and process standards can be modularized or even individualized and adaptively adjusted to the production process.
4. *The product knows the Lean Production environment and can control it:* The control of the production process by the product is already possible today with the available technologies and will soon find its way into many industries. With the help of mobile devices, it is possible to produce custom-made products at standardized conditions. In the Process Learning Factory CiP (www.prozesslernfabrik.de) located at the Institute for Production Management, Technology and Machine Tools, leading components of a product can already be identified at workstations, trigger the configuration of their work instructions, select the appropriate screw- or NC-program.

3. Context-specific requirements for the definition of intended competencies

Different reasons arise for learning factories to re-design their existing curricula. The competencies that are developed in learning factories should address challenges in industry: shorter production life cycles, globalization, demographic change and digitization [9]. Therefore, competency profiles are changing rapidly, whereon learning factories as places of education and training have to react. The curriculum of a learning factory is verbalized by intended competencies. The formulation of these intended competencies is part of the 1st didactic transformation based on the Learning Factory Curriculum-Guide [10]. In this first transformation, context-specific requirements regarding the industrial environment, the organizational targets as well as the target groups are analyzed and transformed to the intended competencies, see figure 2. Later, based on those intended competencies, in a 2nd didactic transformation the socio-technical and didactical infrastructure can be deducted.

Regarding the first requirement field, the competency model is not geared to one specific organization or branch. The goal is to form a competency model that is as specific as possible, but can be applied to as many company scenarios as possible. A good compromise in this case offers the focus on direct production areas of companies mainly from discrete production, which are containing in general manufacturing as well as assembly and logistics tasks. The second requirement field can be described with the goals and strategies of those companies to sustainably boost productivity of their production system by integrating Industrie 4.0 into their existing lean production system. With regard to the third requirement field, it must be differentiated between various roles in the context of Industrie 4.0, possible target groups may be blue-collar workers, supporting functions, and executives, but also several Industrie 4.0-specific roles like I 4.0-system designers, I 4.0-system integrators, I 4.0-system administrators or I 4.0-Process experts. This Lean 4.0 competency model addresses the I 4.0-Process Expert, who is responsible for the design of material and information flows throughout the whole value creating system, conceptualize work organization, leadership routines and others to improve the value creating system. Based on those foci, intended competencies are derived.

Fig. 2. Context-specific requirements for the definition of intended competencies for learning factories, based on [10].

4. Intended Competencies for Lean 4.0 production systems

In the past, different “Industrie 4.0 demonstrators” were established to illustrate the benefits of integrating digital solutions into value creation. In this technology-oriented approach, the didactical concept concentrates on single technical solutions in single processes (see figure 3), a 1:1-transfer of those exemplary technological solutions to the companies’ environments most often does not make sense. An alternative method-based approach is the structuring of intended competencies oriented to lean methods and principles (see figure 3). In this case, digital solutions are seen

Fig. 3. Methods- and technology-based structure of a curriculum.

as an expansion of waste reduction possibilities in production systems. Therefore, following the conception of Lean 4.0, Industrie 4.0-technologies are integrated in existing lean production systems. To adapt and rework the existing curriculum of the Process Learning Factory CiP the method-based approach is used, focusing on the development of technical and methodological competencies in the different learning modules.

So far the curriculum focused solely on competencies regarding lean production. With the findings presented in this paper, a competency gap was identified between the existing curriculum and the change arising from the areas of action (chapter 2) as well as the context-specific requirements (chapter 3). Several experts in the fields of lean production and Industrie 4.0 were involved in the process to create a set of learning modules, which give respect to the presented needs. Figure 4 shows the connections between the learning modules of the CiP curriculum and the areas of action introduced in chapter 2. The curriculum is structured in three phases: “Lean 4.0 Understanding”, “Lean 4.0 Core Elements” und “Lean 4.0 Culture” and comprises 17 learning modules with durations from one to three days.

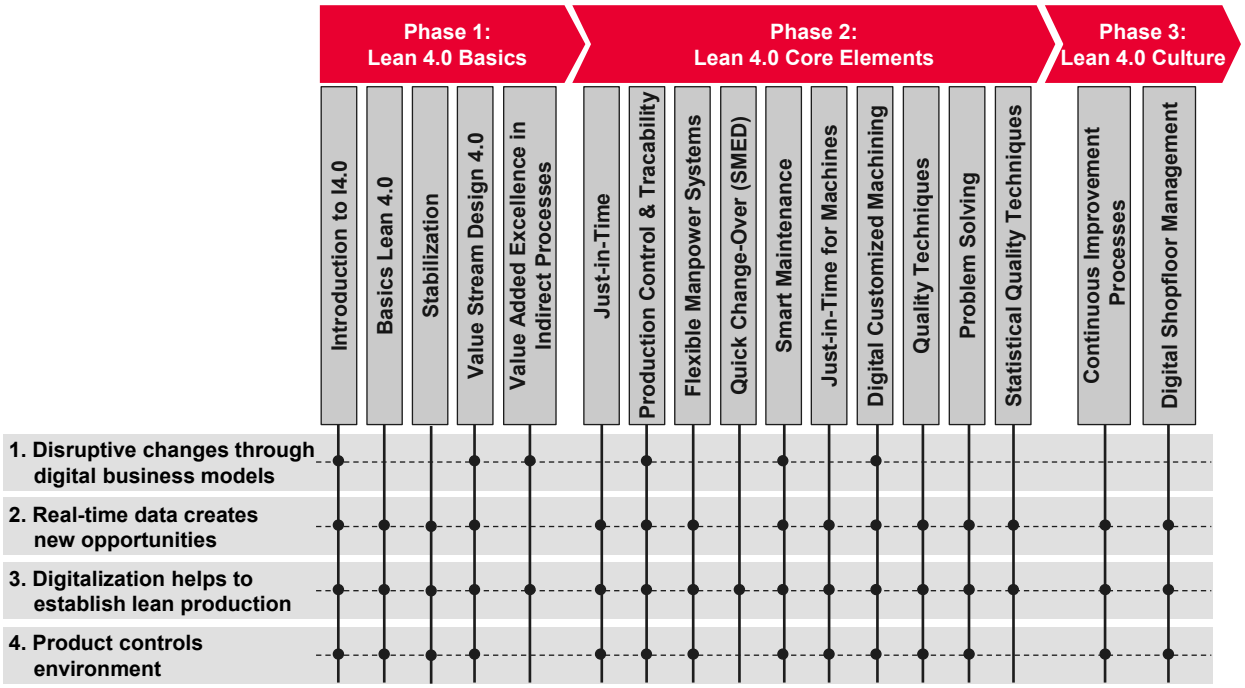

Fig. 4. Connections between the CiP curriculum and the areas of action.

5. Example of a learning module: Basics Lean 4.0

In the next step, the mentioned learning modules are designed in detail based on the intended competencies. Therefore, sub-competencies as well as the necessary knowledge and associated actions, should be identified and formulated [10]. Using the competency transformation matrix and the learning objective taxonomy supports this process [11].

Finally, an example of the learning module is illustrated in this chapter: “Basics Lean 4.0” as a part of the phase Lean 4.0 Understanding. After this course, the participants understand the principles of “Lean 4.0” (see chapter 2) and are able to conduct a value stream analysis 4.0 [12]. Within a value stream analysis 4.0, the material and (in particular) information flow of production systems are analyzed in a six-step procedure. This method is helpful to improve and digitalize production processes and expands the existing value stream analysis by information-logistical forms of waste. This learning module comprises the following learning objectives in figure 5.

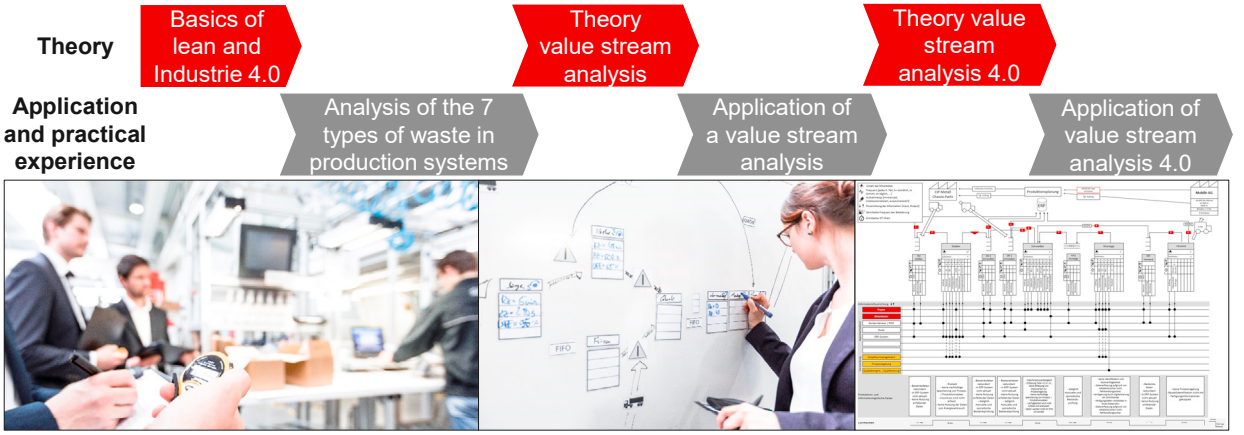

Fig. 5. Learning module "Basics Lean 4.0".

6. Conclusion and Outlook

The necessity to adjust existing curricula arises from new challenges companies face in a changing industrial environment. Against this background also learning factories as places for education and training should rethink their content of learning modules. Especially, the demand for different and new competencies emerges in the frame of an Industrie 4.0 approach. This approach can be aligned with the goals of lean production and can be integrated in existing curricula of learning factories. In doing so, a competency-oriented design is suitable in particular. It supports an analysis of the organizational environment as well as a specification of the target groups.

Based on this, intended competencies can be derived and formulated in detail as shown on the example of the new learning module “Basics Lean 4.0”. Each learning module is questioned, if it still serves the overall target of the learning factory CiP. In the course of this, 12 learning modules will be re-designed competency-oriented to keep the learning factory competitive.

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